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(54) **AUTOMATED SERVICE PROVISIONING IN COMBINATION OF VERTICAL SERVICES AND DIGITAL SUBSCRIBER LINE DOMAINS**

(75) Inventors: **Robert T. Baum, Gaithersburg, MD (US); Eric A. Voit, Bethesda, MD (US)**

(73) Assignee: **Verizon Communications Inc., New York, NY (US)**

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(52) **U.S. Cl.** **370/351; 370/252; 370/420**

(58) **Field of Search** **370/394, 395, 370/397, 399, 401, 409, 412, 465, 466, 467, 470, 474, 252, 420**

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Primary Examiner—Alpus H. Hsu

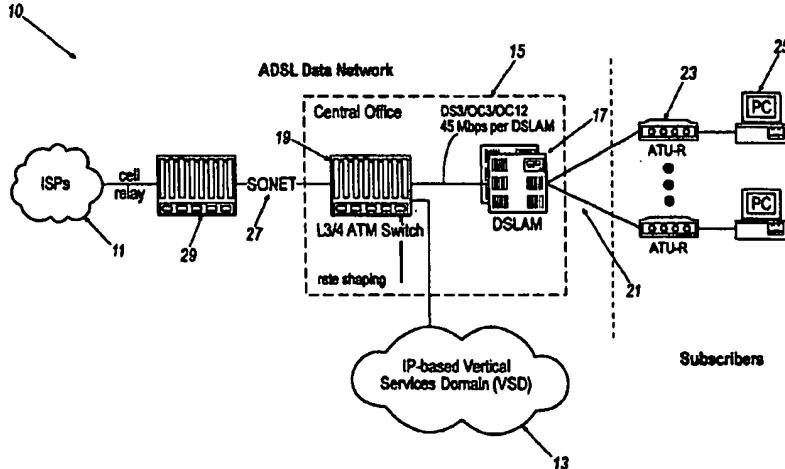
Assistant Examiner—Toan Nguyen

(74) *Attorney, Agent, or Firm*—Leonard C. Suchtya, Esq.; Joel Wall; Rader Fishman & Grauer PLLC

(57) **ABSTRACT**

Offering vertical services to subscribers and service providers is an avenue to immediately improve the competitiveness of digital subscriber line access service, for example of the type offered by a local exchange carrier. To deliver high-quality vertical services, however, the underlying ADSL Data Network (ADN) or the like needs to establish Quality of Service (QoS) as a core characteristic and offer an efficient mechanism for insertion of the vertical services. The inventive network architecture introduces QoS into the ADN, in a manner that enables the delivery of sophisticated and demanding IP-based services to subscribers, does not affect existing Internet tiers of service, and is cost-effective in terms of initial costs, build-out, and ongoing operations. The architecture utilizes a switch capable of examining and selectively forwarding packets or frames based on higher layer information in the protocol stack, that is to say on information that is encapsulated in the layer-2 information utilized to define normal connectivity through the network. The switch enables segregation of upstream traffic by type and downstream aggregation of Internet traffic together with traffic from a local vertical services domain. Systems coupled to the network and software in a user's computer enable a method for automated, end-to-end provisioning of a logical data circuit, in response to a customer's request for bundled broadband services.

10 Claims, 10 Drawing Sheets



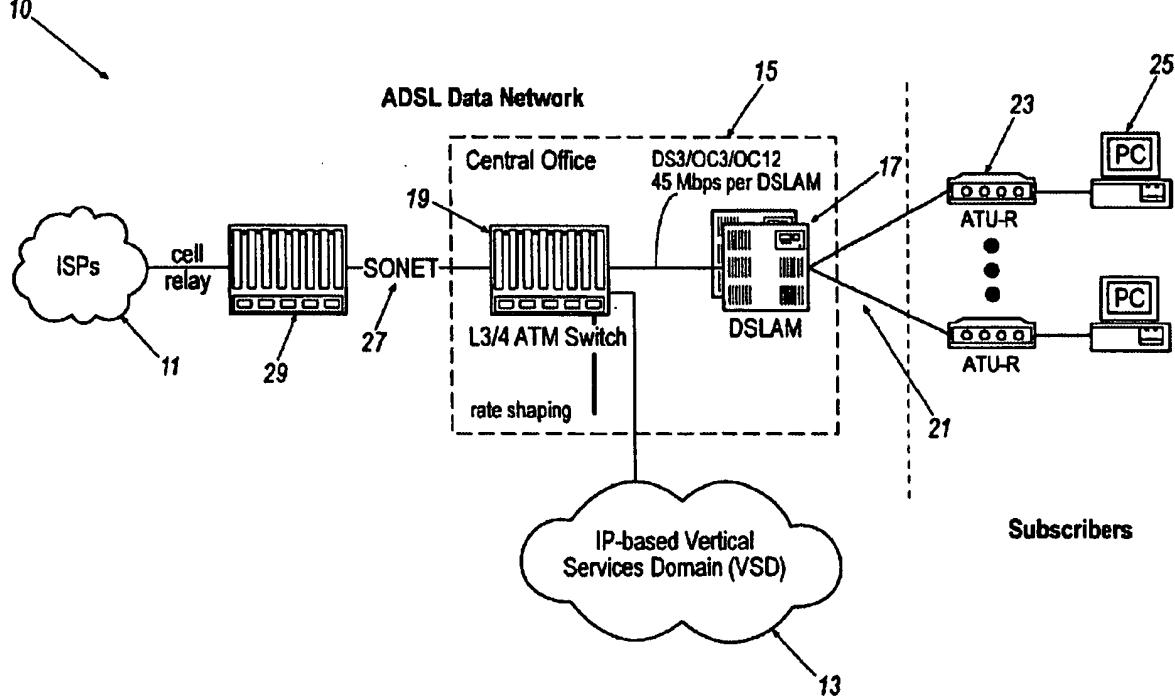


FIG. 1

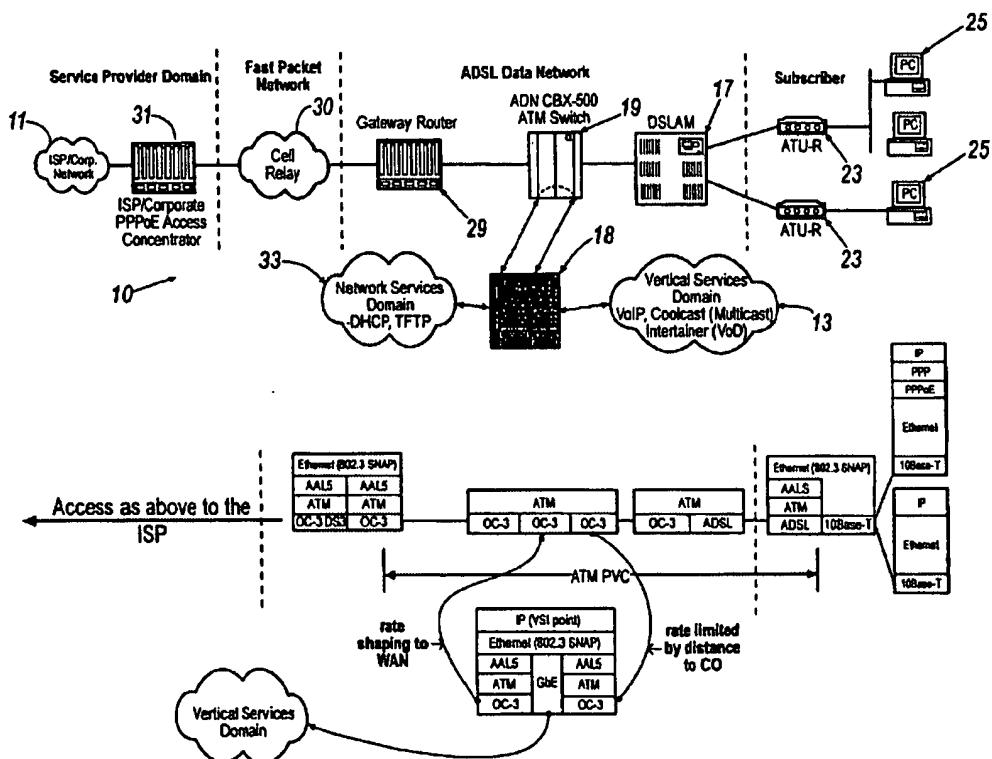


FIG. 2

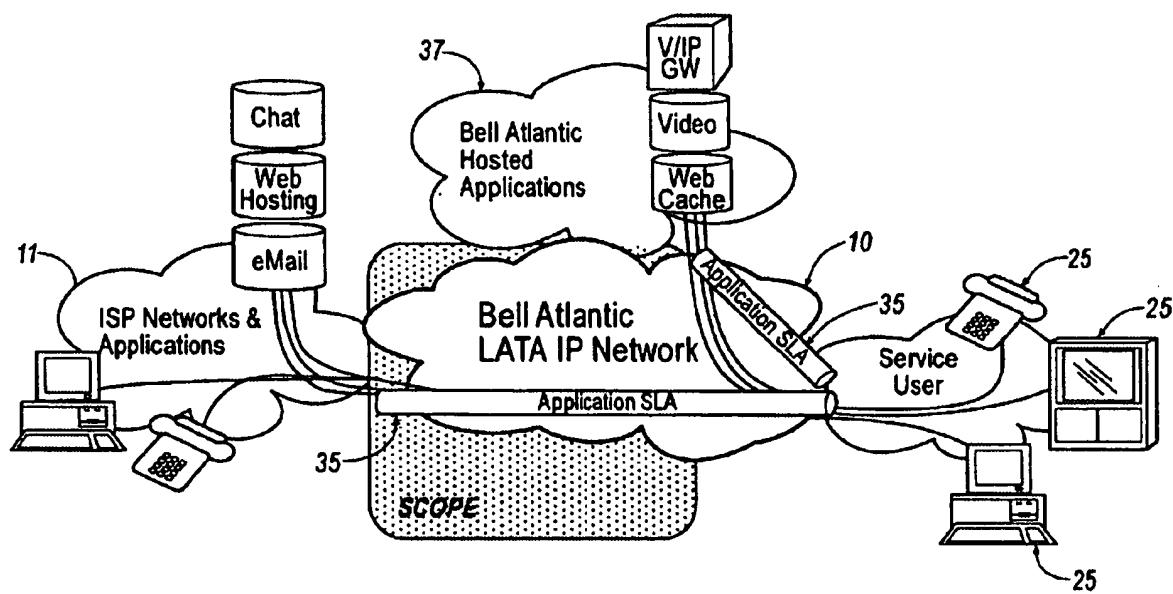


FIG. 3

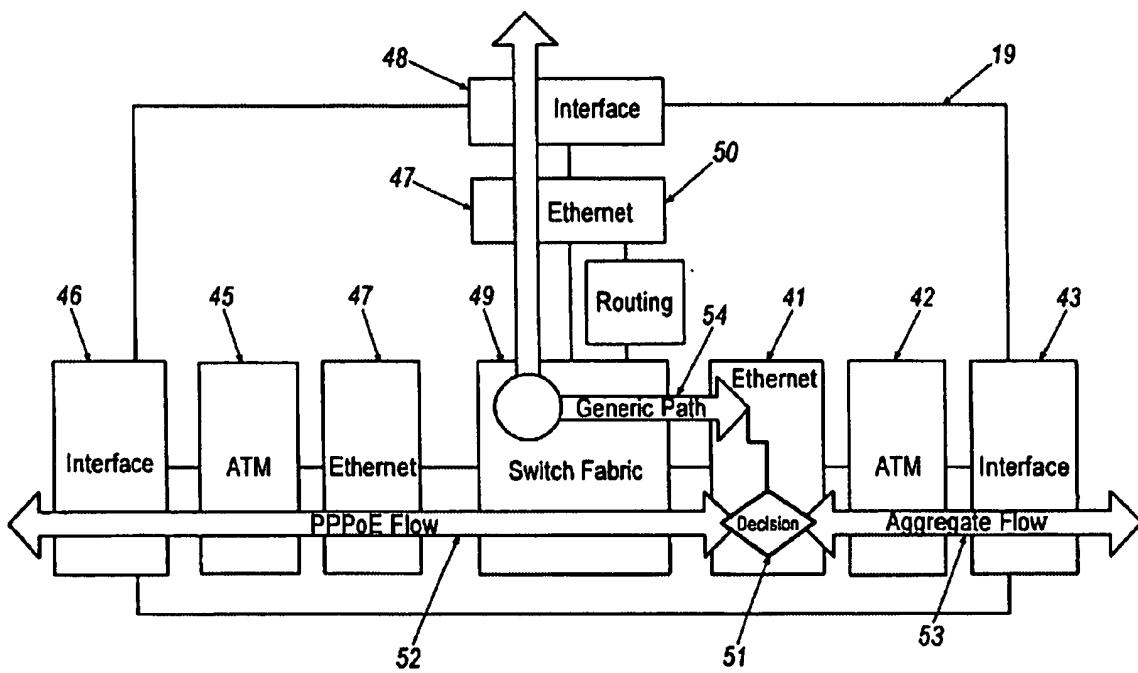


FIG. 4

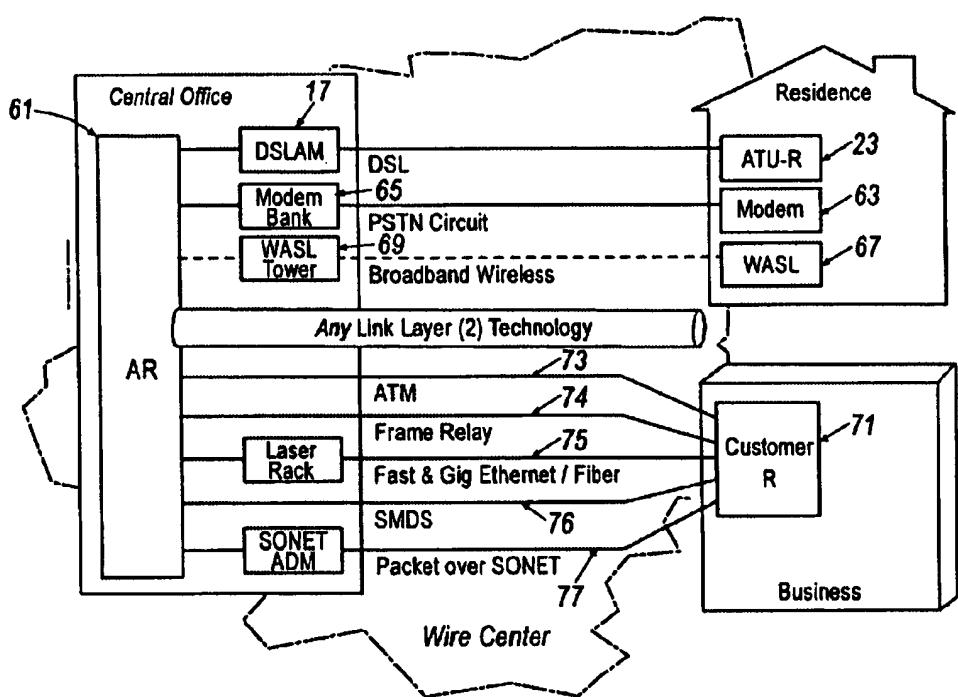


FIG. 5

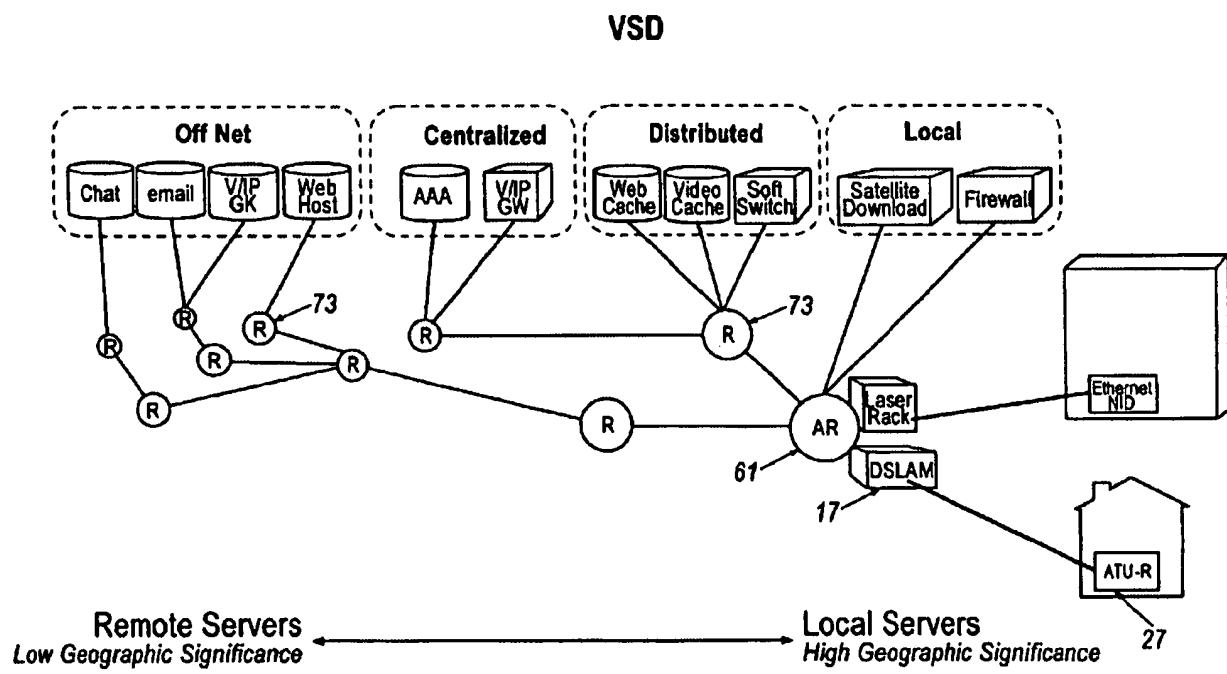


FIG. 6

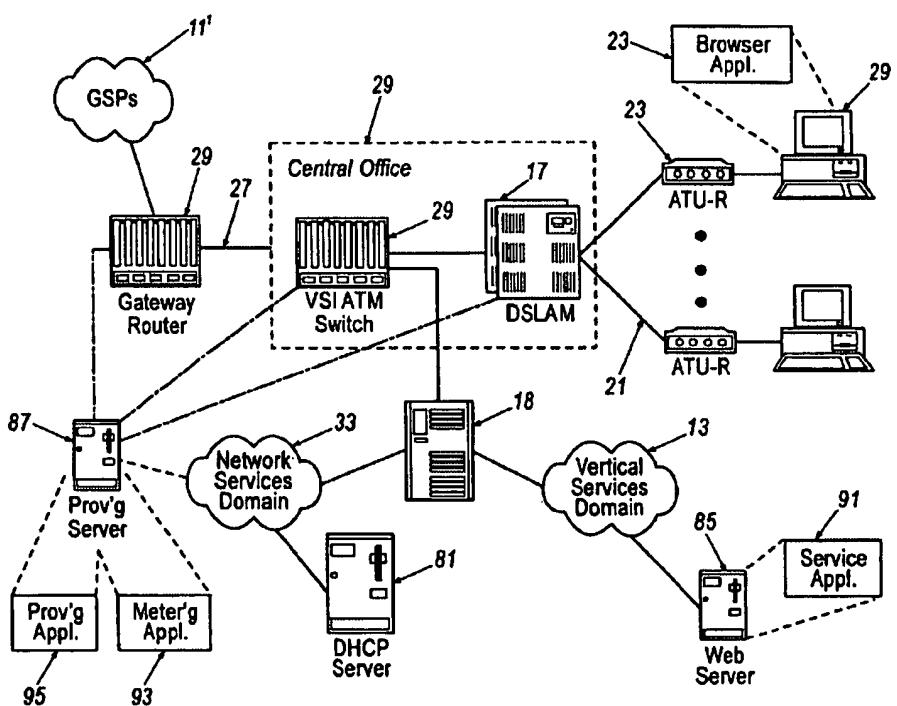


FIG. 7

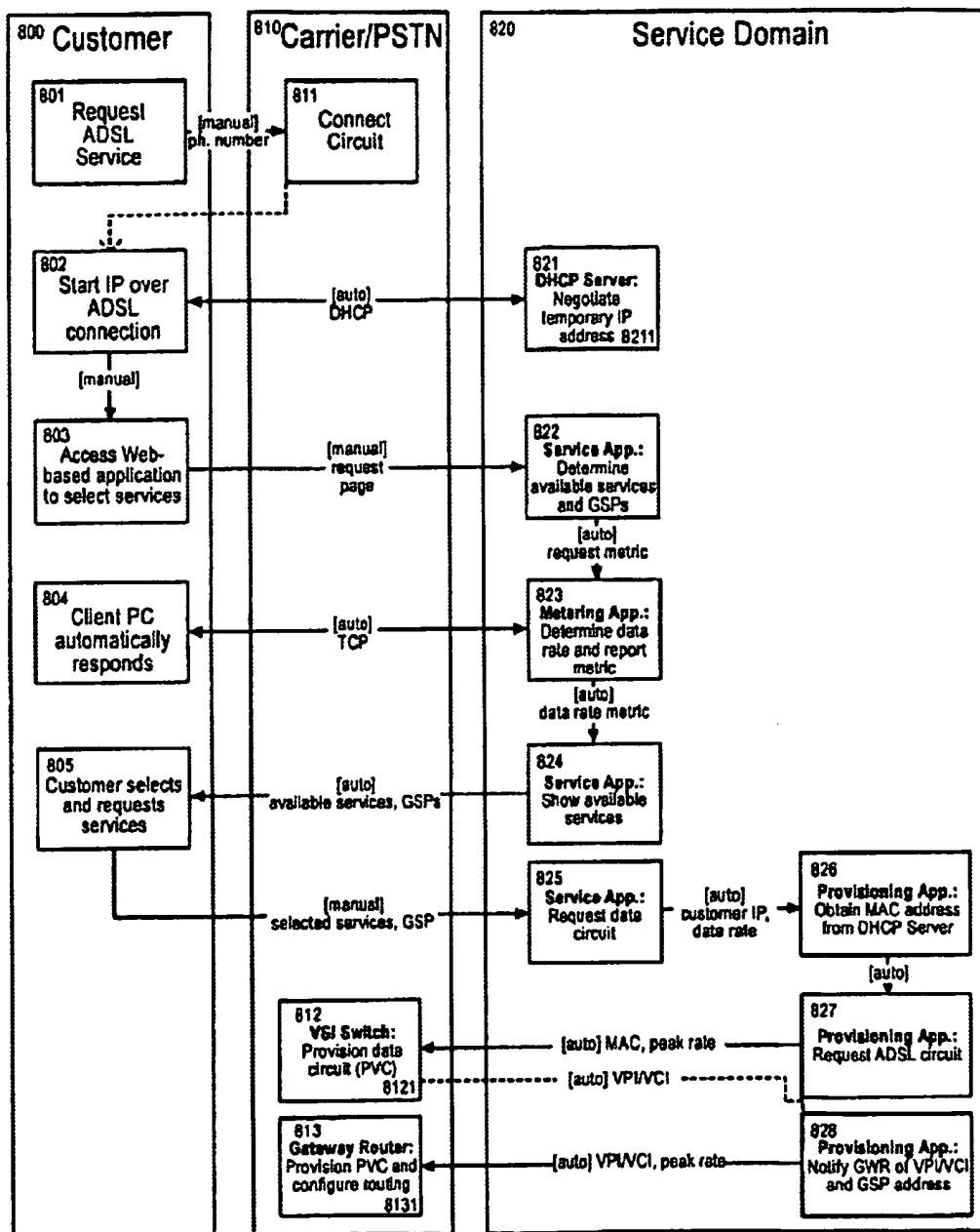


FIG. 8

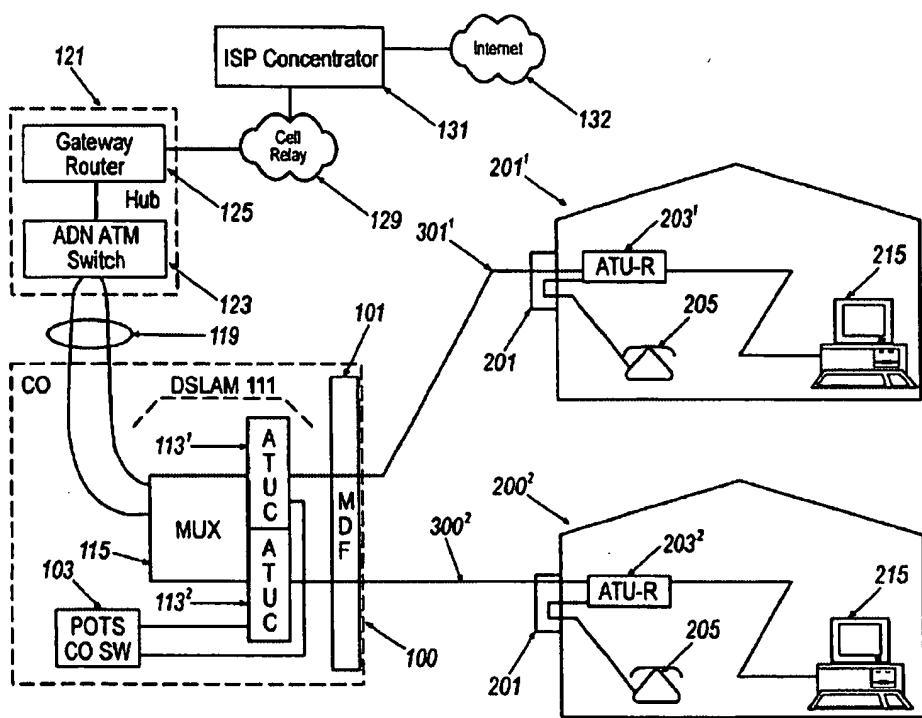


FIG. 9

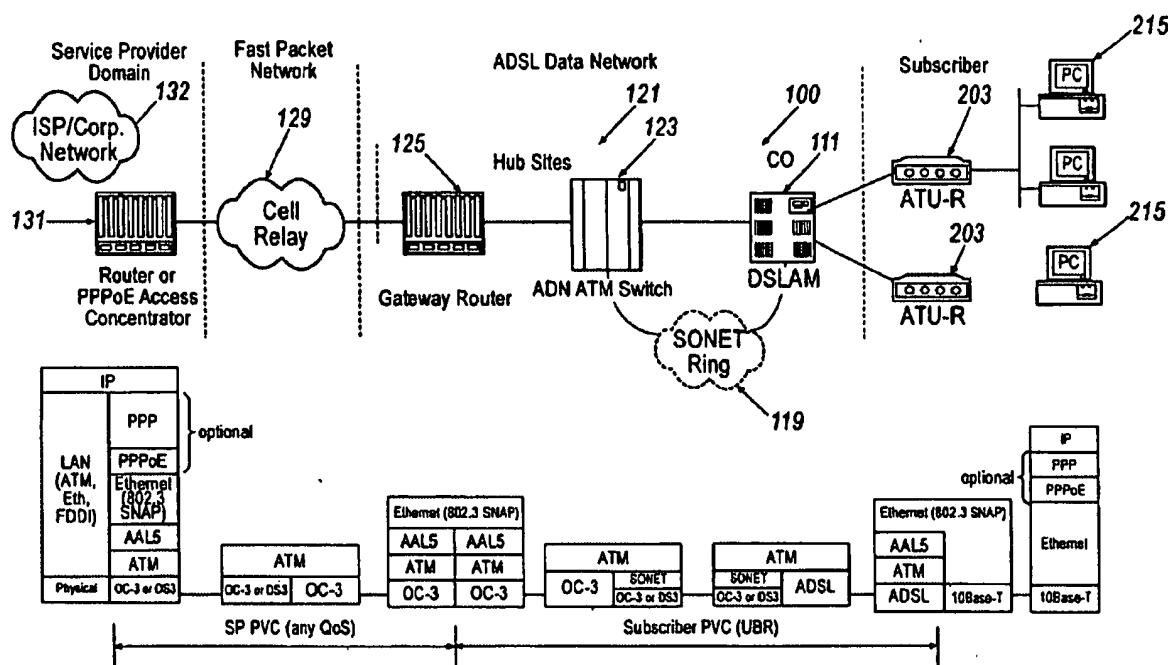


FIG. 10

**AUTOMATED SERVICE PROVISIONING IN
COMBINATION OF VERTICAL SERVICES
AND DIGITAL SUBSCRIBER LINE
DOMAINS**

FIELD OF THE INVENTION

This application is a continuation in part of U.S. patent application Ser. No. 09/635,695, filed Aug. 10, 2000 entitled "SUPPORT FOR QUALITY OF SERVICE AND VERTICAL SERVICES IN DIGITAL SUBSCRIBER LINE DOMAIN" the disclosure of which is incorporated herein entirely by reference.

FIELD OF THE INVENTION

Certain concepts involved in the present invention relate to techniques for implementing data communication services, for example in a local access network utilizing digital subscriber line technology, to support quality of service (QoS) and local introduction of vertical services. Other concepts involved in the present invention relate to techniques for automatically provisioning services through such a network.

BACKGROUND

Modern society continues to create exponentially increasing demands for digital information and the communication of such information between data devices. Local area networks use a network, cable or other media to link stations on the network for exchange of information in the form of packets of digital data. These networks have proven quite successful in providing data communications in commercial applications. However, the common local area network architectures require installation of specialized wiring and use of specific wiring topologies. For example, the most popular network protocols, such as Ethernet, require special rules for the wiring, for example with regard to quality of wire, range of transmission and termination. Furthermore, to extend communications to a wider domain still requires connection of at least one node of the local area network out to a wider area network, such as the network of an Internet Service Provider (ISP). High speed links enabling such wide area access from a LAN domain, for example using T1 lines, are quite expensive and justified only for hi-end commercial users.

The most common form of computer-to-computer communication in use today, particularly for wide area communications, still relies on modems and analog telephone network connections. The telephone-based operation provides the voice grade analog modem a unique power, the necessary connections are virtually ubiquitous. Such modems can communicate via almost any telephone line or wireless telephone (e.g. cellular) to any other such telephone connection, virtually anywhere in the world. The telephone network, however, was designed to provide approximately 3.3 kHz of analog voice bandwidth. Consequently, the data rates that are possible through the telephone network are quite low. Even with a variety of recent enhancements, the data speeds remain at or below 56 kbps.

Integrated Services Digital Network (ISDN) offers somewhat faster data communications and the capacity for concurrent data and voice telephone services. The 160 kb/s capacity carries two bearer (B) channels, each at 64 kb/s, one data (D) channel at 16 kb/s and overhead information in a 16 kb/s embedded operations channel (EOC). The two B-channels may be used separately, for example, for one

voice telephone call and one data communication session. The D-channel typically is used for signaling, for call set-up and the like. Some applications allow aggregation of the channels, to combine the B-channels and possibly the

- 5 D-channel to provide data communications up to the combined rate of 144 kb/s. However, these data rates offered by ISDN already are too slow for many multimedia applications. The high-speed and wide availability of modem personal computers (PCs) continually gives rise to ever 10 more sophisticated multimedia applications. Communications for such applications, typically between the PC and the Internet, already are driving the need for speed to rates far above those available on normal ISDN lines.

A number of technologies are being developed and are in 15 early stages of deployment, for providing substantially higher rates of data communication, for example ranging from 640 kb/s to 7.1 Mb/s. For example, cable television companies are now beginning to offer 'cable modem' services, which allow customers to communicate data over 20 available bandwidth on the coaxial cable of a cable television network. After considering several other options, a number of the local telephone carriers are working on enhancements to their existing copper-wire loop networks, based on various xDSL technologies.

- 25 The term xDSL here is used as a generic term for a group of higher-rate digital subscriber line communication schemes capable of utilizing twisted pair wiring from an office or other terminal node of a telephone network to the subscriber premises. Examples under various stages of 30 development include ADSL (Asymmetrical Digital Subscriber Line), HDSL (High data rate Digital Subscriber Line) and VDSL (Very high data rate Digital Subscriber Line).

The telephone carriers originally proposed use of ADSL 35 and similar high-speed technologies to implement digital video services, for example in networks sometimes referred to as video 'dialtone' networks. The ADSL line technology provided a mechanism for high-speed transport of MPEG encoded video information to video terminal devices in the customers' homes. Examples of such ADSL-based video dialtone networks are disclosed in U.S. Pat. Nos. 5,247,347, 5,410,343 and 5,621,728. The carriers are now deploying a range of xDSL data services targeted at high-speed Internet 40 access and high-speed access to private data networks. U.S. Pat. No. 5,790,548 to Sistanizadeh et al. discloses an 45 example of an ADSL-based data network, e.g. for high-speed access to the Internet and to corporate LANs.

The current design goals of DSL data networks for 50 Internet access do not support high-end vertical services, that is to say services demanding IP-based applications that require assurance of some level of quality of service (QoS). For example, packet-switched Voice over IP (VoIP) requires low latency, low jitter (i.e., a relatively constant bit rate), and 55 non-correlated packet loss. Streaming video has similar requirements, and in addition, requires high bandwidth. DSL data networks designed to support high speed Internet and Intranet access have been optimized to support traffic that is bursty and is not sensitive to latency or jitter. For example, current implementations supporting ATM cell traffic employ 60 the Unspecified Bit Rate (UBR) class of service, which does not provide any bandwidth or delay guarantees.

Consequently, transport of video materials through such 65 DSL data networks inflicts video delays, loss of audio/video synchronization, and image fragmentation.

Furthermore, lengthy bandwidth intensive sessions for video or other broadband applications may degrade the

throughput to all other subscribers served through a shared node, such as a gateway router or a concentrated link. For two-way video, upstream will have even worse quality and throughput problems, due to the best effort nature of the DSL data network implemented for Internet access and because the upstream bandwidth is significantly less than that of the downstream channel.

To appreciate the situation and problems, it may be helpful here to consider an ADSL data implementation of a local access network, as a representative example, in somewhat more detail. FIG. 9 is a block diagram of a typical ADSL data network of the type currently in-use by a number of incumbent and competitive local exchange carriers to provide high-speed access to Internet Service Providers (ISPs) and thus to the Internet. FIG. 10 provides an alternative functional illustration of the elements of such a network. Of particular note, FIG. 10 shows the various protocol stacks in association with the appropriate network elements.

As shown in FIG. 9, a central office (CO) 100 provides plain old telephone service (POTS) and digital subscriber line data service for a number of customers. For purposes of discussion, assume that the equipment at each of the various customer premises 200 connects directly to the CO 100 via twisted pair type copper wiring 300. In an actual implementation, many customers may connect through such wiring to a remote terminal linked to the CO via optical fiber.

At each customer premises 200 in our example, the copper loop 300 carrying both the POTS and ADSL signals connects through a Network Interface Device (NID) 201 placed at the side of the home. A two pair loop is installed from the NID to the location where the ADSL unit 203, typically an ATU-R modem, is located in the home. One pair connects all of the signals on the line 300 from the NMD 201 to the ADSL modem 203. Within the ATU-R type modem 203, a passive splitter/combiner type filter segregates the POTS signal and the data signals. The POTS signal is transmitted over the second twisted pair back to the NID 201. The POTS line is then connected to the in-home wiring extensions at the NID 201, for distribution to one or more standard telephone devices 205 in the home.

Within the ATU-R type ADSL modem 203, the downstream coded ADSL signal is demodulated and decoded to an appropriate data interface protocol for connection to the PC 215. The PC 215 or other data device (FIG. 10) also sends data to the ADSL modem 203. The modem 203 modulates the upstream data and transmits appropriate signals over the line 300, or 300₂, to the corresponding modem 113₁ or 113₂ in the CO 100 (FIG. 9). The ATU-R interface may support bridging, such that multiple users can share the ADSL modem 203, for two-way data communication through the CO 100.

The lines 300 for the customer premises 200 connect through the main distribution frame (MDF) 101 to a Digital Subscriber Line Access Multiplexer (DSLAM) 111. The DSLAM includes a bank of ADSL terminal units of the type intended for central office applications, identified as ATU-Cs 113. The DSLAM also includes a multiplexer/demultiplexer (MUX) 115.

Within the DSLAM 111, each customer line 300 connects to an assigned ADSL terminal unit 113 in the central office (ATU-C). In the example illustrated, the first customer's line 300₁ connects through the MDF 101 to a first ATU-C 113₁ in the CO 100. The second customer's line 300₂ connects through the MDF 101 to a second ATU-C 113₂ in the CO 100. The ATU-C type ADSL units 113 include appropriate

frequency dependent combiner/splitters, for segregating out the voice telephone traffic. Thus each ADSL unit 113 provides a connection for telephone traffic from the associated line 300 to the POTS switch 103.

The ADSL units 113 in the CO (ATU-Cs) essentially act as modulator/demodulators (modems) for sending and receiving data over the subscriber telephone lines 300. On the network side, each of the ATU-Cs 113 connects to the MUX 115. The MUX 115 multiplexes and demultiplexes the upstream and downstream data for the ADSL modems 113 and provides a connection to a high-speed link 119. Through subtending, the MUX 115 may also provide a data concentration for the communications over the link 119.

In a typical implementation, the concentrated data communications utilize a DS-3 link 119. However, because of increasing traffic demands, it is becoming necessary to upgrade the link 119 to SONET optical fiber, such as OC-3 or in some cases even OC-12. The link 119 provides two-way data communication between the central office 100 and a data hub 121. In practice, this is a relatively long or wide area link using expensive interoffice facilities.

On the upstream side, the high-speed interoffice link 119 terminates on an ATM switch 123 for the ADSL data network (ADN). Although only one link 119 appears in the drawing, the asynchronous transfer mode (ATM) switch 123 will typically service a number of DSLAMs 111 in various end offices via similar DS or OC links. The ATM switch 123, in turn, provides a high-speed connection to a gateway router 125 coupled to an ATM cell relay network 129. Typically, the ATM switch 123 will aggregate traffic from a number of such links 119 onto an OC-3 or higher rate SONET link to the router 125. The router 125 and the cell relay network 129 enable transport of ATM cells for the subscribers to and from equipment of one or more internet Service Providers (ISPs), shown by way of example as a concentrator 131 coupled to the public packet switched network commonly known as the Internet 132.

The illustrated local access type ADN network provides ATM cell transport from a customer premises 200 to the ISP concentrator 131. The ATM cells serve as the layer-2 routing or switching protocol for the lowest level definition of connectivity between two points of the network. Higher level protocols ride within the ATM cells.

The ATU-Rs 203 and the customer premises data equipment 215 connect via an Ethernet coupler. The customers' equipment communicates across the ADSL data network utilizing Ethernet, and the wide area communication involves transport of Internet protocol information typically in TCP/IP frames within Ethernet frames. The Ethernet frames carrying the TCP/IP frames are adapted into ATM cells. Attention is directed to the protocol stacks illustrated in the lower half of FIG. 10.

To efficiently provide cell relay, each customer is assigned an ATM virtual circuit that extends from the ATU-R 203 in the respective customer premises 200 to the gateway router 125. Although it was originally envisioned that ATM would support switched logical channels or virtual circuits, to date, such logical switching has proven impractical to implement and administer. Consequently, current practical ATM networks actually utilize permanent virtual circuits, not switched virtual circuits. For a given subscriber, the carrier therefore provisions an ATM permanent virtual circuit from the ATU-R 203 to the gateway router 125. The carrier programs one or more nodes along the path of that logical circuit, particularly the DSLAM 111, to regulate traffic on the virtual circuit to the upstream and downstream rates

corresponding to the grade of service to which the particular customer subscribers. All data traffic for the subscriber goes over the entire length of the permanent virtual circuit, and most if not all nodes along that path limit that traffic to the rates of the subscription as defined in the provisioning data.

The virtual circuit may be thought of as a solid pipe. All traffic passes through the entire length of the pipe-like virtual circuit, regardless of how many switches or other nodes the circuit passes through. The layer-2 protocol defining the circuit carries all of the higher level traffic end-to-end. Higher layer protocols are visible only at the ends of the pipe. Hence, any traffic flow processing intended to utilize the higher layers must occur at some point past one end or the other end of the virtual circuit.

The gateway router 125 also terminates permanent virtual circuits through the cell relay network 129 going to/from the ISP concentrators 131. The gateway router 125 aggregates traffic between a number of subscribers and each respective ISP. The ISP equipment 131 typically implements a variation of a point-to-point protocol (PPP) specifically adapted to ride over Ethernet, referred to as "PPP over Ethernet" (PPPoE). The virtual circuits to the ISPs, however, do not have sufficient capacity to simultaneously carry all subscriber traffic at the maximum rates of the customers' subscriptions. The MUX 115, the ATM switch 123, and the gateway router 125 concentrate and regulate the subscriber traffic going to and from the ISPs, typically on some type of "best efforts" basis.

In a typical Internet access service offering, the most expensive service tier provides 7.1 Mbps for downstream communication and 680 kbps for upstream communication. The next grade of service provides 1.6 Mbps for downstream communication and 90 kbps for upstream communication, whereas the lowest tier of service provides 640 kbps for downstream communication and 90 kbps for upstream communication. The maximum grade of service offered to an individual subscriber depends on the rates for which the subscriber's line can qualify, although the subscriber may opt for a lower rate service since the higher-rate service is more expensive.

The approach outlined above relative to FIGS. 9 and 10 works well for Internet access if the traffic relates to web access, file transfers and the like, which do not require guaranteed quality of service. Various segments of the Internet industry, however, are rapidly developing new multimedia services and applications that already are pushing the capabilities of such a network. For example, increasingly, Internet traffic includes a number of types of communication that require a guaranteed quality of service. Voice telephone communication over IP is extremely sensitive to latency and jitter. The permanent virtual circuits provide an unspecified bit rate (UBR) service and do not guarantee any minimal amount of delay or jitter. Also, because the rates are set by subscription, the service tends to be relatively inflexible. Some services, such as multicasting of broadband information from the Internet into the local access ADN for a large number of concurrent users, can quickly overload one or more nodes or critical links of the network, for example the link 119 between the DSLAM 111 and the ATM switch 123 at the hub 121.

Most industry experts propose to increase the services available via the public Internet. However, because the higher layer protocols are visible only on the Internet side of the virtual circuit "pipe," these services all must be implemented out past the end of the virtual circuit, at least behind the gateway router 129 and most likely in the public

network, where it is possible to view and route based on higher level protocols, particularly Internet protocol (IP). Such a migration strategy to implement new services creates severe problems. For example, in the network of FIG. 9, if a customer at premises 200, desired to order a video on demand, the customer would communicate via the assigned permanent virtual circuit and the ISP to a server on the Internet 132. The server would send the video stream back through the Internet 132, the ISP equipment 131, the cell relay network 129 and the virtual circuit from the router 125 to the ATU-R 203 for handoff to a PC or the like at 215. If the rate of the requested video exceeds the customer's subscription rate, the customer could not view the video in real time during the download. Even if the rate of the requested video is below the customer's subscription rate, loading in the Internet or the local access network may impose delays and/or jitter in communication of some segments of the requested video. Assuming that the hub 121 and the links 119 implement a subscriber concentration, ordering of videos or similar broadband files from the Internet 132 quickly consumes the shared resources through the hub 121 and the links 119, reducing the rates of service provided to other customers seeking concurrent Internet access.

It might be possible to increase the capacity of the links 119 and/or the hubs 121; however, this tends to increase the carrier's recurring costs and often makes the overall service (s) of the ADN network economically impractical.

It has also been suggested to provide customers guaranteed quality of services for some portion of their communications, by segregating the traffic carried between the customer premises and the hub 121. This would require assigning a plurality of ATM permanent virtual circuits to each subscriber, one for each different guaranteed level of quality of service and one for all other Internet traffic for the subscriber. Administration and provisioning of one virtual circuit per subscriber is already complicated, and the number of virtual circuits through any given ATM node is limited by current equipment designs. Expanding the number of permanent virtual circuits per subscriber to support multiple QoS tiers of service therefore would be quite expensive, and the management thereof would become a nightmare. To support an increased number of virtual circuits, many having guaranteed QoS requiring some substantial minimum rate at all times, would also require that the operator substantially upgrade the network to increase the end-to-end capacity all the way to the wide area network 132.

Furthermore, to actually receive the desired QoS requires that all elements involved in the communication must guarantee the desired level or quality of service. For communications across the public Internet 132, this means that various nodes and links on the public Internet must be available and capable of providing a guarantee of the desired QoS. In point of fact, few nodes on the public Internet actually support any type of QoS. Hence, even if the ADN supported a desired QoS, most subscribers would not benefit from that service because their communications over the public Internet would have no QoS guarantee, and would suffer from the usual problems of latency and jitter.

Consequently, current deployments of ADSL-based data networks, such as shown in FIGS. 9 and 10 generate many customer complaints. From the customer perspective, the service does not deliver the data rates that the customer pays for on a consistent basis. The customer typically blames such problems on network equipment failure. In fact, most of the problems already are due to virtual circuit congestion problems, of the kinds outlined above. Essentially, the ADN

network is crippled by the unpredictable nature of the service levels that the customers perceive due to congestion on the ADN and on the public Internet.

Also, with this approach, because all of the major service elements are implemented in servers accessible to the Internet, all of the services are subject to severe security risks. Each service provider's server is accessible to virtually any computer coupled for communication via the Internet. This openness is a desirable feature of the public Internet. However, a consequence is that any such server is accessible to and thus subject to attack from any hacker having Internet communications capabilities. Popular services, particularly those generating substantial revenues, become prime targets for attack.

Another area of problems is that the ADN does not offer the carrier any technique for offering its own differentiated service applications. To compete with other service providers, the carrier operating the ADSL-based data network needs to introduce its own multimedia services, for example, its own video services to compete with video services of cable television companies (that offer competing Internet access services). As noted above, however, introduction of a new service, such as true video on demand or broadcast video requires communications via the public Internet 132. This is true even if the carrier operating the network of FIGS. 9 and 10 wanted to initiate its own video service(s).

Hence, there is an ongoing need to improve the architecture and operation of a digital subscriber line data communication network, particularly to facilitate finer gradation of services within the local network. The need, first, is for such a local network to support introduction of services on a 'vertical' basis within the local access network separate and apart from the common forms of Internet traffic, both for commercial differentiation and for increased security. In a related need, the local network needs to support a number of different levels of quality of service (QoS).

SUMMARY OF THE INVENTION

A general objective of the invention is to implement an enhanced digital communication network for subscriber lines that supports vertical introduction of new communication and/or multimedia services.

A further objective is to support multiple levels or grades of quality of service within the access network.

Another objective of the invention relates to improvement of the cost effectiveness of the data network, for example, by reducing the demand for high-capacity interoffice links while increasing the bandwidth available at the network edge for at least some types of services.

A related objective is to provide a technique for introduction of new high-end services near the network edge, from a domain that is more secure and therefore less subject to hacker attacks.

A further objective of the invention is to support QoS and/or local introduction of vertical services, without the need to assign multiple virtual circuits or the like to each subscriber.

Still further objectives of the invention relate to provisioning of service through an access data network. Specifically, it is an objective of the provisioning related concepts to significantly reduce, or completely remove, the errors present in the existing data circuit provisioning process, which includes: manual ordering processes; manual record-keeping; and manual circuit changes at the PSTN frame and the intermediate ADSL frame.

Aspects of the invention relate to unique methods and network architectures for providing a combination of wide area internetwork service and vertical communication services via a local access network. Other aspects of the invention relate to a particular switch developed to facilitate a unique form of routing, for example to support of QoS and vertical service insertion.

Hence, a first aspect of the invention relates to a method of segregating traffic for at least two different network domains. The method involves establishing a contiguous layer 2 protocol connectivity, upstream from a customer premises to a communication access node coupled to a first network domain. At an intermediate point along the contiguous connectivity, at least two types of upstream transmissions from the customer premises are distinguished, based on information encapsulated within the layer-2 protocol. The methodology forwards each distinguished transmission of a first transmission type from the intermediate point to the first network domain. Similarly, the method entails forwarding each detected transmission of a different second type from the intermediate point to a second network domain, which is logically separated from the first network domain.

Another method aspect of the invention involves providing a combination of access to two different network domains through an access data network. In this case, the actual method includes a step of provisioning a logical communication circuit extending from a customer premises through the access data network to a communication access node coupled to a first network domain. This provisioning comprises defining the logical communication circuit in terms of a layer-2 protocol. An intermediate node along the logical communication circuit examines communicated information in transmissions from the customer premises, for a protocol encapsulated within the layer-2 protocol, in order to distinguish transmission types. The method also includes steps of forwarding transmissions of two different types. A first type of detected transmission is forwarded from the intermediate node to the communication access node, over the logical communication circuit defined in terms of the layer-2 protocol. A second type of detected transmission is forwarded to a second network domain logically separate from the first network domain.

Another aspect of the invention relates to a method involving providing rate adaptive digital subscriber line communications from a digital subscriber line access multiplexer to a plurality of subscribers, over respective subscriber lines. Consequently, the communications can operate at maximum rates that respective line conditions will allow. For each subscriber, wide area access services are provided from an access router node coupled to the digital subscriber line access multiplexer to a node coupled to a wide area internetwork. The rates for the access services conform to service level agreements with respective subscribers. For each subscriber, the method also entails aggregating and segregating communications for a vertical services domain with those for the wide area access services, for combined communication via the maximized-rate digital subscriber line communications.

From a somewhat different perspective, another inventive method offers a combination of wide area internetwork service and vertical communication services through a local access network. This method comprises provisioning a logical communication circuit to support a subscriber-selected grade of service to the wide area internetwork. The logical communication circuit extends from a customer premises of the subscriber to a communication access node coupled to